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# Vegetation's Role on Modifying Microclimate of Urban Resident

Siti Nor Afzan Buyadi*, Wan Mohd Naim Wan Mohd, Alamah Misni

*Faculty of Architecture, Planning & Surveying, Universiti Teknologi MARA, Shah Alam 40150 Malaysia*

**Abstract**

This study focuses on investigation of vegetation growth effect on lowering land surface temperature (LST) within the urban residential area. The area of study is located in residential area of USJ Puchong, Selangor. Two dates of Landsat 5 TM is used to generate land use map, NDVI maps and LST maps. Results show that the replacement of natural green areas into vegetated areas demonstrated significant low temperature of the residential in urban area after 20 years of development. Hence, provide better quality of environment of urban resident and create sustainable development. Subsequently, it is important to consider an environment factors to plan a sustainable urban development, and furthermore to provide a quality environment for urban residents.

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*Keywords:* Vegetation; surface temperature; Landsat Image; urban resident

## 1. Introduction

Increased replacement of the natural greenery area to urbanised areas in previous decades has led to significant changes of local climate conditions. Due to urbanization demand, the rapid growth of urbanization cause reduction of vegetated areas and increase the built-up surfaces. The rationale of this matter is the urban populations are rapidly increasing in size and complexity and more people are leaving rural areas and migrate to urban areas. The temperature distribution in the urban area is significantly warmer than its surrounding suburban areas and experiencing to urban heat island (UHI) (Akbari, 2011; Elsayed, 2009; Misni & Allan, 2010; Giannaros & Melas, 2012; Senanayake et al., 2013).

* Corresponding author. Tel.: +6-019-33577147; fax: +6-035-544-4353.
*E-mail address*: sitiafzan33@gmail.com.


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One of the possible causes of UHI is a drastic reduction of the greener areas to built-up surfaces. The conversion of the natural land cover to built surfaces will be trapped incoming solar radiation during the day and then re-emitted it at night and increased the heat within the built-up areas (Solecki et al., 2004). The UHI effect increases energy consumption for cooling and causes lower thermal comfort in the indoor as well as in outdoor urban environments (Vidrih & Medved, 2013). Therefore, it is vital to apply the mitigation strategy in order to aid the UHI effects at the macro and micro levels. The UHI mitigation strategies such as the use of lighter-colour on the building or reflective surfaces on new developments. However, it is reported that a more practical method of mitigating the UHI is strategic planting of vegetation in urban areas (Ng et al., 2012). Previous study on measuring the potential of tree planting in high density residential areas has been carried out in Manchester, UK (Hall, Handley, & Ennos, 2012). The results showed the tree planting could reduce maximum surface temperature by between 0.5°C and 2.3°C. Previous study defined the capability of matured trees and other vegetation to reduce high temperature in saturated urban area via satellite perspective has been carried out in tropical climate country of Malaysia (Buyadi, Mohd, & Misni, 2013). Several studies in UHI have been carried in tropical country such as Malaysia and Singapore (Elsayed, 2009; Feng, Zhao, Chen, & Wu, 2014; Shahmohamadi, Ramly, & Maulud, 2010). A review of UHI mitigation reports shows that a few strategies are enabled to be implemented in an urban area to counteract the UHI effects such as using cool materials, green roofs, green walls, and planting trees and vegetation (Gartland, 2008). Reviewed literature by Memon et al., (2008) revealed that planting more vegetation has widely been reported as a promising mitigating measure of UHI.

The used of remotely sensed data may provide an objective and globally applicable methodology for assessment of the UHI effect and identified the green space impact on climate condition (Gallo, Tarpley, McNab, & Karl, 1995). Several studies have demonstrated that remotely sensed data can be used in analysis of urban heat islands. Furthermore, the used of satellite images may also help to identified the an irregular pattern of cooler areas within generally warmer urban areas which is known as park cool island (PCI) (Vidrih & Medved, 2013). Satellite images are widely used in monitoring the land use changes, investigate surface temperature distribution and other environmental study (Li, Zhang, & Kainz, 2012; Liu & Zhang, 2011; Senanayake et al., 2013). The role of satellite imagery in monitoring the land use changes is utilized in order to review the past, present and future prospects of climate changes (Gallo et al., 1995). Previous studies have been developed LST using Landsat 5TM to estimate radiation budgets in heat balance studies and as a control for climate models (Buyadi et al., 2013). It is possible to use this technology to investigate the interaction between land cover and local climate (Mohd et.al., 2004). There are few studies that evaluate the UHI effects using satellite imagery and GIS technique (Kolokotroni & Giridharan, 2008; Li et al., 2012; Radhi et al., 2013 and Shahmohamadi et al.,2011).

Previous studies clearly demonstrated that the implications of rapid urban growth were decreased vegetated areas, increased the surface temperature and modified the urban microclimate. However, temperatures in the vegetated area and its surrounding keep the temperature lower than the developed areas. Additionally, maturity of the trees and vegetation will be considered as a vital parameter to ensure the temperature keep lower in urban area through its shadow and transpiration process. Furthermore, trees and vegetation also act as natural agent in against air pollution which is exposed to unhealthy living environment to urban residents. Thus, the green space within the road or other impervious surfaces can create a cooling effect that extends to the surrounding areas. Temporal spatial evaluation and climate estimation using satellite images such as Landsat or ASTER is vital to determine the climate pattern and changes could be monitored continuously. The used of GIS and ERDAS software and statistical method are acceptable as technical methodology in analyzing environmental behaviour especially in combating UHI for past, present and future. This study attempts on investigation of vegetation growth effect on lowering surface temperature distribution within the urban residential area.

## 2. Study area

The study area consists of part of the Petaling District, Selangor. The area is selected due to rapid urban residential development activities over the last 20 years. The extent of the small study area is shown in Figure 1 a), b) and c). The climate of the cities is categorized as a hot and humid tropical climate which is hot and humid, along with abundant rainfall, especially during the Northeast Monsoon seasons from October to March. Temperatures tend to remain constant with maximum values of between 31°C and 33°C, while the minimum between 22°C and 23.5°C.

Relative humidity is around 72–78%. The geographical location of the study area is shown in Figure 1. In addition, meteorological data obtained from the permanent local weather station of Subang, Shah Alam was provided by Malaysia Meteorological Department (MMD). The data obtained coincide with the time and date of the Landsat satellite pass. Landsat 5 TM image dated 21st February 1991 and 21st January 2009 are used.


Fig.1. Location of study area: a) Selangor Map b) Part of Petaling District and c) Detailed Residential Area (USJ Puchong, Selangor).

Source : Google Map, 2013

## 3. Methodology

The methodology involves in this study are given in the following sub-sections.

### *3.1 Generation of land use/land cover*

The detail of satellite image data (Landsat 5 TM) used in this study dated on 21st February 1991 and 21st January 2009 are acquired from the Malaysian Remote Sensing Agency (ACRS). The total temporal of 18 year period is selected to ensure the vegetation growths in the selected areas are well matured. The main activity of the study area is housing/ settlement area and consists of terrace house and single house. The process of generating land use maps is carried out using the ERDAS Imagine digital image processing software. The percentages of land use/land cover of study areas are later calculated. These values of land use/land cover can use to estimate the land use/land cover types individually for each year..

### *3.2 Generation of Normalized Difference Vegetation Index (NDVI)*

GIS spatial analysis and zonal statistical analysis technique are used to visualize the vegetation fragmentation and surface temperature distribution. Equation 1 is used to calculate the NDVI of the study area (ERDAS, 2008). The proposed emissivity values from different NDVI range; i.e.; NDVI<0.2 (bare soil), 0.2<NDVI<0.5 (mixture of bare soil, vegetation and hard surfaces) and NDVI> 0.5 (fully vegetated) are 0.99, 0.98 and 0.98 respectively.

$$NDVI = (NIR - R) / (NIR + R) \quad (1)$$

*Where NIR - the pixel digital number (DN) of TM Band 4 and R – DN of TM Band 3*

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### 3.3 Land Surface Temperature (LST) Retrieval

To measure the surface temperature distribution, the TM thermal infrared data (band 6) is obtained by applying the mono-window algorithm (Qin et al.,2001). The 120m pixel resolution then resampled to 30m resolution to suit the output of urban green space profile. The mono-window algorithm requires three parameters; emissivity, transmittance and effective mean atmospheric temperature (Sobrino et al., 2004). These two parameters (i.e. atmospheric water vapour content and the near surface air temperature) are then used to calculate the air transmittance and effective mean atmospheric temperature (Liu & Zhang, 2011). The third parameter is emissivity, which is calculated from the normalized difference vegetation index (NDVI). The mono-window algorithm equation is given as:-

$$T_s = \{a(1\text{-}C\text{-}D) + [b(1\text{-}C\text{-}D) + C + D]T_i - DTa\} / C \qquad (2)$$

where:- Ts is LST in Kelvin; a = -67.355351; b = 0.458606; (C = $\varepsilon_i$ x $T_a$ ;where $\varepsilon_i$=emissivity can be computed from NDVI ); D = (1- $T_a$) [1+(1- $\varepsilon_i$ )x $T_a$]; $T_i$ is the brightness temperature (K) and $T_a$ is the effective mean atmospheric temperature.

## 4. Results and discussion

The results of this study are presented in four main sub-sections i.e. land use/land cover maps, land surface temperature distribution, NDVI assessment and evaluation based on the vegetation growth within eighteen years.

### 4.1. Land cove changes

Figure 2 shows the land use/land cover maps generated from the Landsat images of 1991 and 2009 as part of residential area in Petaling District (i.e.: USJ Puchong). The major land use/land cover for the detailed study areas are built-up (housing area), mix vegetation (low density trees), open area (barren land), and high density trees (matured trees and wide canopy trees). The total acreage of the study area is approximately 720.09 hectares. The detail acreage of individual land cover of the study area is listed in Table 1. Over the period of 18 years, there is significant increase in the built-up areas (residential area), mix vegetation (low density trees) and high density trees (matured trees and canopy trees) land cover categories by 18.52% to 44.27%, 1.62% to 34.55% and 0.16 to 0.57% respectively. Subsequently, the dramatic changes occurred on cleared land. The cleared land decreased due to its conversion to built-up areas by 81.09% to 1.69%. Although there is significant increase in built-up areas, the mixed-vegetation area also increased. This is due to more trees being planted to replace the lost of natural greenery within the study area.

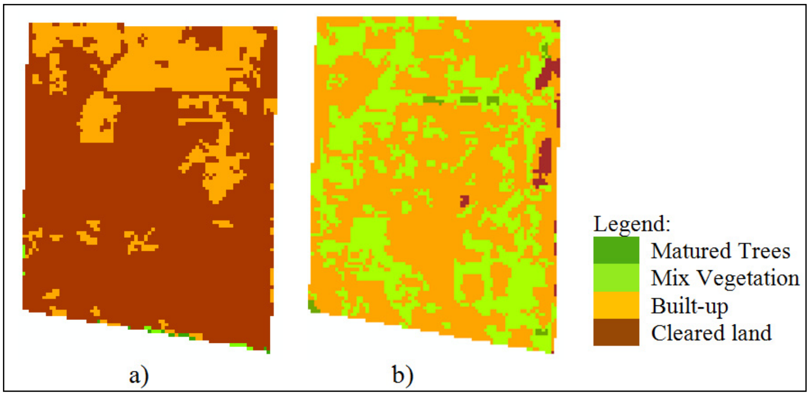



Fig..2. Land use/Land cover maps of USJ residential area in a) 1991 and b) 2009.

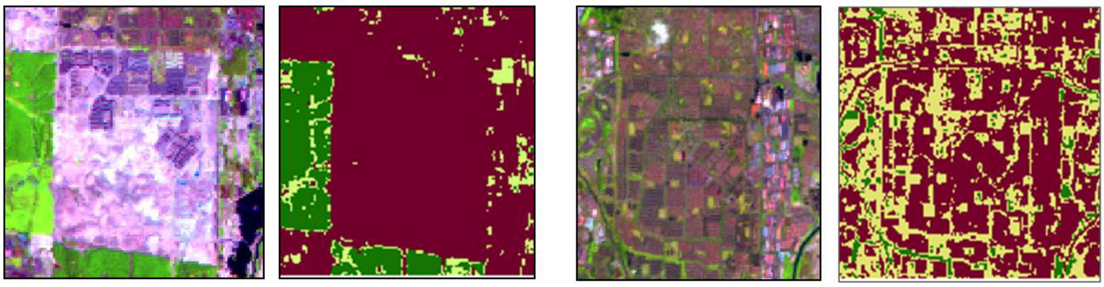
Table 1. Land use/ land cover coverage areas.

| Land use/ Land cover class | Area in Hectare 1991 | Percentage (%) | 2009 | Percentage (%) | Changes (%) |
|---|---|---|---|---|---|
| (1) High Density Trees | 1.17 | 0.16 | 5.31 | 0.73 | +0.57 |
| (2) Mix Vegetation | 1.62 | 0.23 | 250.47 | 34.78 | +34.55 |
| (3) Built-up | 133.38 | 18.52 | 452.16 | 62.79 | +44.27 |
| (4) Cleared land | 583.92 | 81.09 | 12.15 | 1.69 | -79.40 |
| Total | 720.09 | 100 | 720.09 | 100 | |

### *4.2. Analysis of Normalized Difference Vegetation Index (NDVI)*

Figure 3 b) and d) show the NDVI maps generated from the Landsat 5 TM imagery for the year 1991 and 2009. The increase in the vegetation growth coverage within the study area can clearly be seen. This could be due maturity of the trees grown within the residential areas. As more trees and vegetation within the study area are getting matured, the NDVI value increase and hence lowering the LST (refer to Figure 5). Furthermore, Figure 4 shows the statistical evaluation of the NDVI growth of the study area. Based on the Figure 4, cumulative NDVI of vegetation growth in 1991 and 2009 are increased and the total value of matured trees and vegetation in 2009 is higher than 1991. As shown in image satellite and NDVI map of 1991 (refer Figure 4 a) and c)), the area was under construction to residential areas of USJ Puchong. Meanwhile, as shown in Figure 4, the cumulative negative NDVI value of 1991 represent the study areas was covered by open space without vegetation.

However, in 2009 the satellite image and NDVI map (Figure 3) show that the area was converted to built-up surface which the area become saturated as residential area. The positive cumulative NDVI value in 2009 (Figure 4) also represents the increased volume of trees and vegetation within the residential areas. The NDVI map of 2009 shows that even the area was covered by impervious surfaces of residential area, the planted trees and vegetation was growth within the residential area as linear trees or open space will help to reduce the emittance of impervious surfaces hence lowering the temperature of built up surfaces by its shade and shadow. Therefore, landscaping and planting trees and vegetation within the built-up or new cities can be considered as initiative plan to reduce the high temperature of urban area as well as to replace the degradation of natural green areas such as forest.



a) b) c) d)

Legend:

<0.2 : Cleared Land/ Built-up Area

0.2≤NDVI<0.5 : Mix of Built-up/ Bare Soil and Vegetation

≥ 0.5 : Fully Vegetated

Fig..3. Satellite image of Puchong residential area in a) 1991 and c) 2009 and vegetation growth pattern in b) 1991 and d) 2009.

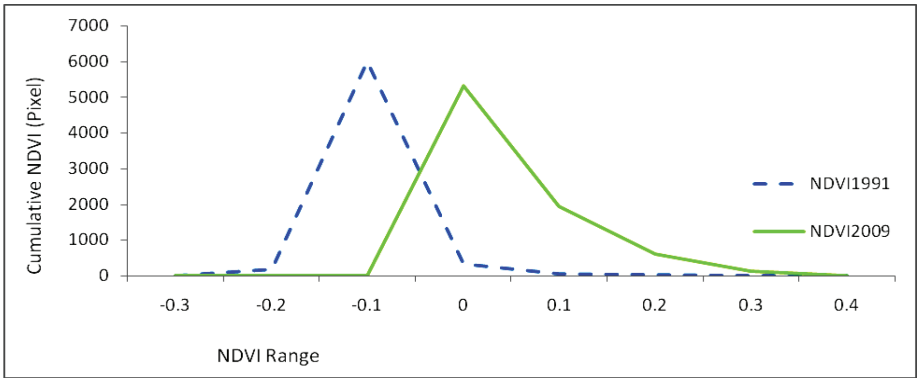



Fig. 4. Cumulative NDVI pattern changes of two different dates.

### 4.3. Land surface temperature

The surface temperature distributions of 1991 and 2009 are shown in Figure 5. The mean temperature for individual land use/land cover is summarized in Table 2. Based on Figure 5 and Table 2, the lowest and highest radiant temperature for 1991 are 27.35°C (in the high density tree area) and 29.6°C (in the built-up area) respectively. Meanwhile, for 2009 the radiant temperatures range between 25.0°C and 32.0°C. The highest mean temperature is within the cleared land and while the lowest is within high density trees. The implication of urban development by replacing natural vegetation (forest) to built-up surfaces such as concrete, stone, metal and asphalt clearly can increase the surface radiant temperature. The vegetated area such as high density trees and mix vegetation areas still show a considerable lower radiant temperature in both years, because dense vegetation can reduce the amount of heat stored in the soil and surface structures through shadow and evapotranspiration. The textures of land cover include land use types, changes in land use and land cover can have profound effects on the surface radiant temperature. This green area is provided for a basic 10% minimum requirement of open space in any development in Malaysia (Act 172, Town and Country Planning Act 1976). The green area also include urban reserve along the roads in developed urban area. The impact of vegetation growth within the residential area creates the cooling effect to the surrounding residential area, and modified the microclimate of urban residential area.

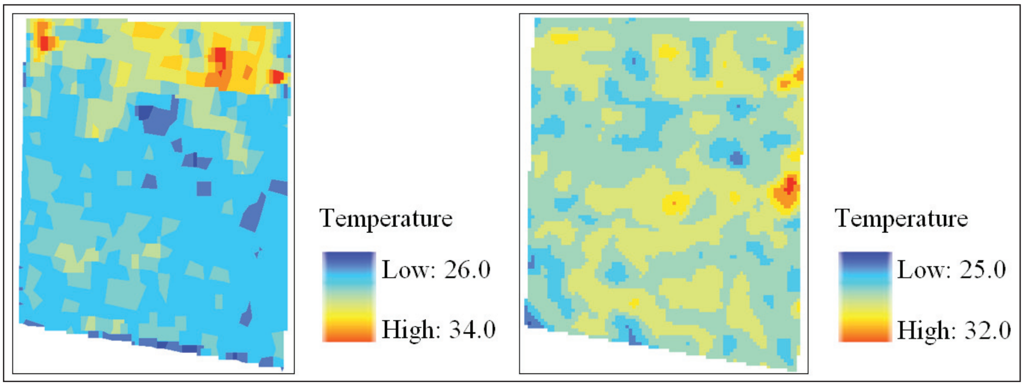



Fig.5. Surface temperature distribution map in a) 1991 and b) 2009.

Table 2. LST distribution within different land use/land cover.

| Land use/ Land Cover | 1991 (Temperature °C) | 2009 (Temperature °C) |
|---|---|---|
| High Density Tree | 27.35 | 27.21 |
| Mix Vegetation | 27.42 | 27.08 |
| Built-up | 29.60 | 28.40 |
| Cleared Land | 29.18 | 29.27 |

## 5. Conclusion

The results of this study suggest that the drastic land use changes from cleared land to urban residential area may influence the mean temperature distribution. However, even in smaller green areas such as linear trees along the road or cluster tree planting at neighborhood parks within the residential area might also provide notable cooling benefits and modified the microclimate of the surrounding areas by it shadow and during evapotranspiration process at daytime. Such findings illustrate the different temperature of vegetated area was 1.32ºC cooler than built-up (residential). These initial findings may help researchers to understand the trees and vegetation cooling effects and provide urban planners practical guidelines for designing green residential areas and parks with stronger cooling effects to counteract the adverse impacts of UHI. In the other hand, this study also will help urban planners or urban designers to understand the interaction between vegetations' role and UHI effects especially in a hot and humid tropical climate region like Malaysia to mitigate the UHI phenomenon. The used of GIS and ERDAS software in monitoring the climate change pattern can be considered as a vital technical method before the ground observation can be implemented. However, the further research should be including detailed studies on the vegetation cooling effect based on various vegetation types or vegetation categories.

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